Analysis of Canada Goose Band Recovery Data from Southern Illinois Bandings, 1939-76

III. Recovery and Survival Characteristics

A Progress Report to:

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PREFACE

This is the third in a series of interim reports to present progress made toward analysing recovery records of Canada geese banded in southern Illinois. The first two reports provided a comprehensive summary of the banding and recovery data, and analysis of the distributional characteristics of band recoveries. They were prepared under contracts with the Illinois Department of Conservation and the U. S. Fish and Wildlife Service covering the period October 1, 1978 to June 30, 1979. The present report was prepared under a continuation of these contracts covering the period July 1, 1979 to June 30, 1980.

A final report will be prepared for publication. It will be a synthesis of previous reports, and will contain new material as well as revision of previous results and conclusions. The progress reports present our preliminary findings. In the process of extending and synthesizing these results, some conclusions have been modified or changed.

This series of reports is the result of more than 35 years of commitment and cooperation between many individuals and agencies. Our efforts would not be possible without the contributions made by all those who participated in banding, recovery and data management programs which have provided the data base for this contribution to the management of the Mississippi Valley Population of Canada geese.

Our analysis of distribution and survival utilizes the recoveries of more than 117,000 geese banded in southern Illinois under the banding permits of the Illinois Department of Conservation (permit 7224)--72.8 percent, Horseshoe State Game Refuge (permit 6362) and Illinois Natural

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History Survey (permit 6507)--14.2 percent, and Crab Orchard National Wildlife Refuge (permit 6688)--15.0 percent.

Sizable contributions within these programs were made by several individuals. Arthur Hawkins and Harold Hanson of the Illinois Natural History Survey banded at Horseshoe Lake Refuge during the 1940's and 1950's, respectively. In later years, Dennis Raveling of Southern Illinois University banded at Crab Orchard National Wildlife Refuge while George Arthur and Dave Kennedy banded large numbers of geese at Horseshoe Lake and Union County refuges.

Nearly 18,000 recoveries of shot geese have been reported through the 1977-78 hunting season. These are the principal data for our analyses of distribution and survival. Banding and recovery records for this study were obtained from the computer retreival files of the Bird Banding Laboratory at Laural, Maryland.

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INTRODUCTION

This progress report presents estimates of survival and recovery rates for Canada geese (Branta canadensis) banded in southern Illinois from 1941 through 1977, and recovered through the 1977 hunting season. It is intended to provide managers with additional information about the history of MVP geese, and to contribute to current knowledge of population processes of Canada geese in general.

Estimation of population characteristics from band recoveries have been reported for Canada geese from several wintering areas (Hanson and Smith 1950, Vaught and Kirsh 1966, Chapman et al. 1969, Greib 1970, Hanson and Eberhardt 1971). In the MVP, only the early band recoveries have been evaluated (Hanson and Smith 1950). There exists no overall examination of population characteristics of MVP geese from banding data collected since 1950.

Specific objectives of this study are the following.

1) Estimate annual recovery and survival rates for MVP Canada geese,
2) Evaluate sex, age and subpopulation differences in survival and recovery,
3) Evaluate temporal changes in annual survival rates.

BACKGROUND ON THE MVP

Three distinct periods coincide with the banding history of MVP geese: 1) the years of population decline, 1941-47; 2) the years of recovery and rapid growth, 1951-56; and 3) the years of slower, controlled growth, 1957-76. Survival and recovery rates are only two, albeit important, aspects of population change during these years. In part, they reflect the changing management practices that have occurred. Thus a brief history of the MVP will provide a useful background. Reeves et al. (1968) discuss the major events of these years.

When banding began, Horseshoe Lake refuge held the largest wintering concentration of MVP geese. A majority of the MVP harvest occurred along the refuge periphery on hunting clubs formed at adjacent farms. The fall harvest in this area became increasingly excessive. To combat a rapidly declining population, the Secretary of the Interior terminated goose hunting in Alexander County during 1944 and 1945 after 21 days and 5 days, respectively. The southern Illinois goose population after the 1945 season was 22,000, the lowest ever recorded.

In an effort to rebuild goose numbers several steps were taken. The 1946 hunting season was closed to goose hunting in the entire Mississippi flyway. A small increase was noted in the population as a result. In 1947, the season was reopened for 30 days, but the daily bag and possession limit was reduced to one. Also 20,000 acres of Alexander County was entirely closed to goose hunting. In addition, Union County State Refuge (6500 acres) and Crab Orchard NWR (44,000 acres) were established to serve as satellite refuges on which to redistribute the

geese. Hazing at Horseshoe Lake Refuge was conducted until 1949 to aid in this effort.

As the population increased, hunting restrictions were relaxed. By 1951, the southern Illinois wintering population had reached nearly 100,000 with flocks at Crab Orchard and Union County contributing significantly to the total. In the same year, water control structures were completed at Horicon Refuge in each central Wisconsin and 24,000 geese were attracted to the area. In later years, migrational stops at Horicon were made by an increasingly larger proportion of the MVP.

MVP Harvest during the 1950's was controlled mainly by statewide regulations. There was much variation in the annual harvest. In 1953 and 1957 there were excessive harvests credited with causing temporary population declines. As harvest pressure increased in both Illinois and Wisconsin, a need for stricter control of the harvest was emerging. The result was a quota system established in 1960 around the refuges at Horicon and Southern Illinois. Under quota zone regulation, the MVP was allowed to increase steadily, reaching a post-season population of over 400,000 in 1976-77.

SOUTHERN ILLINOIS BANDING DATA

This study concerns geese banded post-season, and secondarily with those banded pre-season in southern Illinois refuges at Horseshoe Lake, Union County and Crab Orchard Lake. Available data is summarized by Wright and Kasul (1979a).

Bandings of approximately 92,000 post-season geese from 1941-77 were included. All were normally handled and released. Game farm and experimentally handled or treated geese were not used. Age at banding was identified by banders as juvenile (½ year) or adult (1½+ years) for all geese. Sex was known for 30 percent of these. Banding volume varied considerably during these years. Approximately 6000 bnadings were available during 1941-47, 14,000 during 1951-60, 54,000 during 1961-70, and 17,000 during 1971-77 (Table 1). The precision with which annual survival and recovery rates were estimated varied with banding intensity. We used approximately 12,000 reported recoveries of geese shot during an identifiable hunting season through 1977. A hunting season was defined from September 1 through January 20. It included recoveries in Canada and the United States.

Pre-season geese were treated as separate data. We utilized 4500 pre-season bandings in 1964-70 (Table 1) from which 762 recoveries were reported through 1977.

Pre-season banded geese are first subject to harvest shortly after banding. Thus newly banded pre-season juveniles are first recovered as juveniles. Newly banded post-season geese, however, are first recovered in the following year. They are first recovered as yearlings. Interpretation of recovery and survival rates must reflect this difference. To

Table 1. Summary of annual southern Illinois banding used in Survival estimates.

Calendar Year	Post-Season			Pre-Season		
	Juveniles	Adults	Median Date	Juveniles	Adults	Median Date
1941	144	107	2-02			
1942	275	82	3-01			
1943	418	251	1-27			
1944	439	461	12-25-43			
1945	478	227	1-05			
1946	103	74	12-03			
1947	295	207	11-22-46			
1951	107	528	12-17-50			
1952	272	497	12-18-50			
1953	752	923	1-08			
1954	155	338	1-22			
1955	223	266	2-01			
1956	172	420	1-23			
1957	653	942	1-09			
1958	394	587	1-03			
1959	279	529	1-12			
1960	279	428	1-07			
1961	884	730	1-12			
1962	170	474	2-12			
1963	777	933	2-05			
1964	842	1419	1-09	211	171	10-27
1965	4024	2675	2-03	72	160	10-12
1966	4261	1556	1-29	531	1013	10-27
1967	5637	4210	1-07	482	641	10-31
1968	5977	2887	2-07	109	244	10-23
1969	5419	2541	2-14	162	393	10-24
1970	2754	3503	1-09	263	237	10-29
1971	2526	2191	2-23			
1972	2706	1701	2-01			
1973	1493	1723	1-31			
1974	2135	1329	2-22			
1975	2439	1329	1-24			
1976	3134	1283	2-02			
1977	2530	1632	2-07			

avoid confusion, we consistantly refer to the 5-8 month old geese banded pre-season as juvenile and those banded post-season as young.

ESTIMATION OF SURVIVAL AND RECOVERY RATES

The estimation of survival and recovery rates are based on the methods of Brownie and Robson (1976). They present several statistical models of the survival and recovery process, and for each model, they develop estimators for recovery and survival rates as well as associated variances, covariances, and statistical hypothesis tests. These models were used to estimate rates for Canada geese where two age classes were identified at banding, and survival and recovery rates were different for young and adults. They have previously been used to evaluate population characteristics in mallards (Hooper et al. 1978). The two age models are an advancement of earlier, although conceptually similar, models allowing analysis of adult banded individuals only (Seber 1962, 1970; Robson and Youngs 1971). These models have been applied to adult banding data in Pintail (Anderson and Sterling 1974) and mallards (Anderson 1975, Anderson and Burnham 1976).

Many of the calculations presented here were performed using a computer program (Brownie) obtained from the FWS Bird Banding Laboratory at Laurel, Maryland. The models and some of the associated statistical tests used here are described in a handbook by Brownie et al. (1978). We use their notation and terminology in this paper.

Survival and recovery are annual rates that correspond approximately to the one year period from the mid-point of one banding season to the mid-point of the next consecutive banding season (Table 1). Recovery rate (f) is the probability that a banded goose alive at the beginning of a period, is shot during that period's hunting season and reported to

the FWS. Survival rate(s) is the probability that a banded goose alive at the beginning of one period survives all sources of mortality to reach the beginning of the next period.

As an illustration, if N_1 geese are banded in an experiment and R_{11} and R_{12} recoveries are reported in the next two hunting seasons, then we can write

$$R_{11} = N_1 f_1 \tag{1}$$

and

$$R_{12} = N_1 S_1 f_2. \tag{2}$$

In equation (1), f_1 is the first year recovery rate. It is the proportion of banded geese that are reported in the first hunting season after banding. The number of banded geese that survive the entire year is $N_1 S_1$ where S_1 is the first year survival rate. Thus the second year recovery rate f_2 in equation (2) is the proportion of these remaining geese that are reported in the second hunting season after banding. If recoveries are collected for a third hunting season, the number of recoveries is $R_{13} = N_1 S_1 S_2 f_3$ with the new parameters defined in the same manner as above. In a banding experiment several consecutive years of banding are generally conducted, instead of the single year illustrated here, and recoveries are recorded for several years.

Model Selection

Our objective was to estimate recovery and survival rates such that the assumptions of the models chosen for presentation adequetely reflected the corresponding recovery and survival process of the population. The recovery data, shown here for one age class only, was summarized in the following way.

$$\begin{array}{lllllll}
\text{BANDED} & \text{RECOVERED} & & & & & \\
N_1 & R_{11} & R_{12} & R_{13} & R_{14} & \cdots & R_{1\ell} \\
N_2 & & R_{22} & R_{23} & R_{24} & \cdots & R_{2\ell} \\
N_3 & & & R_{33} & R_{34} & \cdots & R_{3\ell} \\
\vdots & & & & \vdots & & \\
N_k & & & & R_{kk} & \cdots & R_{k\ell}
\end{array}$$

There are K consecutive years of banding and recoveries are recorded for some $\ell \geq k$ consecutive hunting seasons. Since each R_{ij} can be expressed in terms of survival rate(s) and recovery rate (f), we wanted to estimate these rates so that they acceptly fit the observed data, i.e., the observed R_{ij}.

Estimates are derived from two models in this report. Their structure, expressed in terms of survival and recovery rates, are given in Table 2.

Model H_1 (Brownie et al. 1978: 59): This is a very general model of the survival and recovery process requiring the estimation of many parameters. Assumptions of the model are the following.

1) Young and adults have different survival and recovery rates.
2) Adult survival and recovery rates are constant with respect to age.
3) Recovery rates vary from year to year in both young and adults.
4) Survival rates vary from year to year in both young and adults.

For these assumptions, annual estimates are made for recovery rate of young (f_i', i=1 to k), recovery rate of adults (f_i, i=1 to k), survival rate of young (S_i', i=1 to k-1), and survival rate of adults

Table 2. Expected recoveries for certain models expressed in terms of survival and recovery rates.

Number Banded	Expected Recoveries			
Adult		Model H		
N_1	N_1f_1	$N_1S_1f_2$	$N_1S_1S_2f_3$	$N_1S_1S_2S_3f_4$
N_2		N_2f_2	$N_2S_2f_3$	$N_2S_2S_3f_4$
N_3			N_3f_3	$N_4S_4f_4$
N_4				N_4f_4
Young				
M_1	$M_1f'_1$	$M_1S'_1f_2$	$M_1S'_1S_2f_2$	$M_1S'_1S_2S_3f_4$
M_2		M_2f_4	$M_2S'_2f_4$	$M_2S'_2S_3f_4$
M_3			$M_3f'_3$	$M_3S'_3f_4$
M_4				$M_4f'_4$
Adults		Model H		
N_1	$N_1f'_1{}''$	$N_1S_1f_2$	$N_1S_1S_2f_3$	$N_1S_1S_2S_3f_4$
N_2		$N_2f'_2{}''$	$N_2S_2f_3$	$N_2S_2S_3f_4$
N_3			$N_3f'_3{}''$	$N_3S_3f_4$
N_4				$N_4f'_4{}''$
Young				
M_1	$M_1f'_1$	$M_1S'_1\ f_2$	$M_1S'_1S_2f_3$	$M_1S'_1S_2S_3f_4$
M_2		$M_2f'_2$	$M_2S'_2f_3$	$M_2S'_2S_3f_4$
M_3			$M_3f'_3$	$M_3f'_3f_4$
M_4				$M_4f'_4$

(S_i, i=1 to k-1) for each year of banding i.

Model H_2 (Brownie et al. 1978: 73): This is a more general model than H_1. Assumptions of this model are the following.

1) Juveniles and adults have different rates of recovery and survival.
2) Adult survival rates are constant with respect to age.
3) Recovery rates of adult banded geese are different the first year than in later years.
4) Recovery rates of adults are constant with respect to age beginning in the second recovery year.
5) Recovery rates vary from year to year in both juveniles and adults.
6) Survival rates vary from year to year in both juveniles and adults.

It is similar to model H_1 except that the first year recovery rate of adult banded geese is different from adult recovery rates in later years. In this model an additional k-1 recovery rates, f_i''', are estimated.

Two types of statistical tests were used to select these models from the several available alternatives (Brownie et al. 1978: 8). First a contingency table χ^2 test was used for each model considered to test the hypotheses that the model fit the data versus the general alternative that it did not fit. This is a test of whether the expected R_{ij} calculated from knowledge of N_i and the estimated S and f are close to the observed R_{ij} of the data. Second, tests specifying more specific alternative hypotheses about survival or recovery rates were used

to examine the nature of recovery or survival rates. These are explained where they are applied.

Z Tests For Differences Between Years

Comparison of survival or recovery rates between two groups of years is made using a Z statistic (Brownie and Robson 1974; Brownie et al. 1978: 180). This test has been applied to evaluate the difference in recovery rates between years having liberal versus conservative hunting regulations (Anderson 1975, Anderson and Brunham 1976). The Z statistic is a linear combination of the estimated parameters of the form

$$Z = \frac{\bar{f}_L - \bar{f}_C}{\sqrt{\mathrm{Var}\ (\bar{f}_L) + \mathrm{Var}\ (\bar{f}_C) + 2\mathrm{Cov}\ (\bar{f}_L, \bar{f}_C)}}$$

where $\bar{f}_L$ is the mean annual survival rate in years having liberal harvest regulations and $\bar{f}_C$ is the mean annual survival rates in years having conservative harvest regulations. We make extensive use of the Z statistic for similar applications in tests of survival and recovery rates. Unless otherwise indicated all Z tests are two-sided tests.

RESULTS AND CONCLUSIONS FROM POST - SEASON BANDINGS

Estimates for Young and Adults 1941-77

Estimates of annual survival and recovery rates were made using model H_1 of Brownie and Robson (1976) where data for sexes and refuges were pooled. Three distinct periods were considered: 1) the early years of banding (1941-47), the years of statewide regulation (1951-59), and the years of quota zone regulation (1960-77). For the periods 1951-59 and 1960-77, goodness of fit tests indicated that models specifying more parameters were unnecessary and models specifying fewer parameters did not fit the recovery data (Table 3). While a simpler model was adequate for 1941-47, we used H_1 for comparison with the later years.

For 1941-47, the mean annual recovery rate was .034 for young and .031 for adults. This included the years 1944 and 1945 when goose hunting seasons were restrictive and 1946 when no goose hunting was allowed. Mean annual survival for 1941-46 were .77 and .75 for young and adults respectively (Table 4). The small samples of banded geese were reflected in the large variances associated with the estimates.

Larger samples of banded geese beginning after 1950 resulted in more precise estimates for most later years. All of our conclusions were based upon the post-1950 results. From 1951-76 estimated annual survival rates varied from .38 to .97 in young and .48 to more than to 1.00 in adults (Tables 5 and 6). Survival estimates greater than 1.00 observed in adults for some years were attributable to large covariances between estimates in consecutive years, random sampling errors, and possible bias in the estimates resulting from a less than perfect fit of model H_1 (Table 3). Mean survival was .71 and .81 for young and adults,

TABLE 3. Hypothesis tests concerning properties of survival and Recovery rates from Post-season banding.

		1941 - 47			1951 - 59			1960 - 77		
Test	Null Hypothesis	X^2	df	Signif.	X^2	df	Signif.	X^2	df	Signif.
Same Young and Adult										
Fit of H_0	Year varying S&f	105.8	94	.19	184.4	152	.04	366.7	247	<.001
Different Young and Adult										
Fit of H_{02}	Constant S_1 Year varying f	130.2	94	.01	209.1	167	.03	328.5	250	.01
Fit of H_1	Year varying S&f	89.9	80	.21	137.7	132	.35	239.5	214	.21
Fit of H_2	Year varying S&f, 1 yr age dependent f	87.7	74	.13	129.0	123	.34	221.1	199	.14
H_{02} vs. H_1	Constant S	16.7	11	.12	44.6	17	<.001	84.2	30	<.001
H_1 vs. H_2	Age dependent f 1st yr only	2.2	6	.90	8.7	9	.54	18.4	15	.24

TABLE 4. Annual Survival and recovery rate estimates for the years 1941 - 47.

Year beginning late January	Estimates and Standard errors							
	Young Recovery		Adult Recovery		Young Survival		Adult Survival	
	f'	S.E.	f	S.E.	S'	S.E.	S	S.E.
1941	.049	.018	.056	.022	1.27	.470	.776	.338
1942	.040	.012	.027	.011	.822	.179	.536	.193
1943	.048	.010	.051	.010	.606	.112	.636	.125
1944[1]	.032	.008	.034	.006	.387	.081	.594	.103
1945[2]	.021	.006	.035	.007	.941	.337	1.400	.505
1946[3]	.000	.000	.002	.001	.591	.181	.538	.195
1947	.017	.007	.014	.004				
AVERAGE	.034	.005	.031	.004	.769	.108	.747	.068

[1] 21 day hunting season only

[2] 5 day hunting season only

[3] No hunting season in Mississippi Flyway

TABLE 5. Annual Recovery and Survival estimates for the years 1951 - 1959.

Year Beginning late January	Juvenile Recovery		Adult Recovery		Juvenile Survival		Adult Survival	
	Rate	SE	Rate	SE	Rate	SE	Rate	SE
1951	.047	.020	.034	.008	.658	.175	.838	.111
1952	.037	.011	.048	.007	.623	.106	.720	.085
1953	.061	.009	.052	.006	.487	.071	.695	.087
1954	.039	.016	.040	.006	.452	.119	.783	.121
1955	.054	.015	.056	.008	.499	.110	.821	.124
1956	.006	.006	.048	.006	.700	.142	.788	.094
1957	.061	.009	.055	.005	.379	.048	.480	.046
1958	.152	.018	.105	.009	.935	.149	1.250	.155
1959	.036	.001	.043	.005	.652	.148	.804	.130
AVERAGE	.055	.004	.053	.002	.598	.041	.798	.018

TABLE 6. Annual Recovery and Survival estimates for the years 1960 - 1977

Year Beginning late January	Juvenile Recovery		Adult Recovery		Juvenile Survival		Adult Survival	
	Rate	SE	Rate	SE	Rate	SE	Rate	SE
1960	.032	.011	.028	.004	.655	.133	.726	.111
1961	.050	.008	.033	.007	.581	.081	.734	.100
1962	.012	.008	.031	.005	.753	.185	1.120	.148
1963	.034	.007	.026	.004	.744	.092	.754	.083
1964	.034	.006	.028	.003	.873	.088	.763	.064
1965	.032	.003	.024	.002	.690	.052	.796	.061
1966	.035	.003	.024	.002	.653	.037	.796	.056
1967	.026	.002	.029	.002	.765	.043	.853	.005
1968	.031	.002	.027	.002	.829	.054	1.040	.072
1969	.036	.003	.026	.002	.841	.051	.806	.057
1970	.039	.004	.030	.002	.824	.072	.855	.067
1971	.035	.004	.023	.002	.880	.086	.838	.081
1972	.031	.003	.020	.002	.751	.075	.796	.083
1973	.042	.005	.032	.003	.750	.092	.659	.074
1974	.030	.004	.037	.003	.918	.120	.877	.115
1975	.028	.003	.027	.003	.772	.113	.723	.110
1976	.037	.003	.032	.004	.836	.145	.791	.143
1977	.036	.004	.032	.004				
AVERAGE	.033	.001	.028	.001	.771	.024	.819	.010

respectively. There are somewhat higher than estimates given elsewhere for Canada geese (Chapman et al. 1969, Greib 1970, Hanson and Eberhardt 1971). Mean recovery rates for the same years was .041 for young and .037 for adults. Recovery rates varied annually from .01 to .15, but annual variation was not more than .02 in most years (Tables 5 and 6).

Two types of tests were used to evaluate observed differences in recovery and survival rates between young and adults. First, a chi-square test of the hypothesis that young and adults had identical rates of survival and recovery [Fit of H_o] was rejected for 1951-59 ($P < .001$) and 1960-77 ($P < .001$). It was concluded that young and adults had different rates of recovery and/or survival. Secondly, we employed Z tests to examine the mean annual survival rates and mean annual recovery rates between young and adults. These are presented and discussed in the next section.

Statewide versus Quota Zone Regulation

The post-1950 years were divided into two periods. From 1951-59 Canada goose harvest was controlled by statewide regulations covering bag and possession limits and season lengths. A quota system of regulation was initiated in 1960 in the vicinity of Horicon Refuge in Wisconsin and the southern Illinois refuges.

Under statewide regulation from 1951-59 mean annual survival was .60 for young and .80 for adults (Table 5). Using a Z-test the lower survival of young was significant ($Z = 3.6$, $p < .001$). For the same period, mean annual recovery was .055 and .053 for young and adults, respectively. Recovery rates were essentially the same for both ages ($Z = .47$, $p > .65$).

Under quota zone regulation from 1960-77, mean annual survival was .77 for young and .82 for adults (Table 6). This difference was not as clear as found for 1951-59 ($Z = 1.85$, $p < .05$ in a one-tailed test, $.10 < p < .05$ in a two-tailed test). Mean annual recovery rate was .033 for young and .028 for adults. The lower recovery rate for adults was significant ($Z = 3.5$, $p < .001$).

Both periods showed a similar pattern toward a higher survival rate for adults. However, several differences were also evident. First, recovery rates of young and adults were similar under statewide regulation, but under quota-zone regulation adults had lower recovery rates. Second, Z tests indicated that mean annual survival was higher in young under quota zone regulation ($Z = 3.86$, $p < .001$), but survival was similar for adults during both periods ($Z = 1.0$, $p < .3$). Third, extremes of variation were greater under statewide regulation even though these were fewer years in the sample. Survival of young had a range of .38 - .94 under statewide regulation and .65 - .97 under quota zone regulations. The range for adult survival was .48 - 1.00 and .66 - 1.00 for the respective periods. Recovery rates were more variable in 1951-59 than during 1960-77. The range of juvenile recovery rates were .006 - .152 under statewide regulation and .012 - .042 under quota zone regulation. Adult recovery rates ranged .04 - .105 and .02 - .033 for these periods.

Average annual recovery rates were also lower under quota zone regulation in both young ($Z = 5.3$, $p < .001$) and adults ($Z = 11.2$, $p < .001$). These differences are attributable to two indistinguishable sources, lower harvest rates or lower reporting rates during the later

period. In general, there was a steady decline in recovery rates since 1951 for both young and adults.

Temporal Variation in Survival and Recovery Rates

The significant differences found in both recovery and survival rates between the years of statewide regulation (1951-59) and quota-zone regulation (1960-77) suggest that temporal variation occurred in both parameters. Within each of these periods, temporal variation in survival and recovery rates are also observable (Tables 5 and 6). Statistical tests of the constancy of annual survival and recovery rates within each period are considered separately.

A 2xn chi-square was used to test the hypothesis that recovery rates were constant from year to year. Separate tests were conducted for recovery rate of young and the first-year recovery rate of adult banded geese. For 1951-59, the recovery rate of young ($\chi^2_8 = 71.7$, $p < .001$) and first year recovery rate of adults ($\chi^2_9 = 47.2$, $p < .001$) were found to vary from year to year. For 1960-77, the recovery rate of young ($\chi^2_{17} = 2192.3$, $p < .001$) and adults ($\chi^2_{16} = 3.14$, $p = .01$) was also found to vary temporally. Despite the statistical significance in the later period, the range of variation was small (Table 6).

Three tests were used to examine annual variation in survival rates. The first was a test that adult and young survival rates were both constant (Model H_{02}) versus the alternative that survival varied temporally in young and/or adults (Model H_1) in the presence of variable recovery rates (Brownie et al. 1978: 87). Temporal variation was detected in 1951-59 ($p < .001$) and 1960-77 ($p < .001$) (Table 3).

We have concluded that temporal variation was present in young and/or adults. We next examined each age class separately to determine which age classes exhibited temporal variation in survival.

The hypothesis that the survival rate of young was constant year to year was tested using a generalization of the Z test (Grizzel et al. 1969) and the survival estimates and sample covariance matrix of these estimates from Model H_1. The hypothesis that survival rates in all pairs of successive years were equal was rejected for 1951-59 ($\chi^2_8 = 20.3$, $p < .01$) and 1960-77 ($\chi^2_{16} = 26.3$, $p < .05$).

Annual variation in survival of adults was examined using recovery data for adult banded geese and the single age class models of Robson and Youngs (1971). Average annual survival for adults (Model 1) in 1951-59 (.81) and 1960-77 (.82) was similar to the estimates from the two age models (Tables 5 and 6). A test of whether adult survival was constant each year (Model 2) versus the alternative that survival varied temporally (Model 1) in the presence of variable recovery rates indicated that survival varied temporally during 1951-59 ($\chi^2_8 = 32.3$, $p < .001$) and 1960-77 ($\chi^2_{15} = 48.9$, $p < .001$).

From these tests, we have concluded that recovery rates and survival rates of both young and adults varied temporally from 1951-77. Survival rates exhibited large temporal differences in both age groups while recovery rates varied over only a small range (Tables 5 and 6).

Sex Specific Differences

The hypothesis that males and females had the same survival and recovery rates was tested using a goodness of fit test proposed by Brownie et al. (1978: 148). Sex was determined for only 30 percent of

banded geese, thus sample sizes for this test were small for most years.

Sufficient observations for a valid, although not powerful, test in the case where young and adults are distinguished were available from bandings in 1963-1971 where data for refuges was pooled. The test, equivalent to testing whether the parameters fit under H_1 are the same for males and females, was not conclusive ($\chi^2_{44} = 51.7$, $p > .10$).

To increase sample size and the years of comparison, young and adult data were pooled. A test for differences between males and females was a test of the null hypothesis that parameters fit under Model 1 were the same for both sexes. No significant differences between males and females were detected for 1941-47 ($\chi^2_{26} = 26.5$, $p > .45$). Less conclusive results were obtained for 1951-60 ($\chi^2_{28} = 37.6$, $p > .10$) and 1961-77($\chi^2_{32} = 45.3$, $.10 \leq p \leq .05$). In both of the latter periods, most of the significance was attributable to a single year; in most years male and female parameters were quite similar. We have concluded that differences between males and females occasionally occurred, however, a conclusion of consistant overall differences was not justifiable.

Refuge Specific Differences

Although Horseshoe Lake, Union County and Crab Orchard refuges are in close proximity to one another, and winter flights between the refuges are not uncommon, differences in survival or recovery rates have been suggested (Kennedy and Arthur 1974). Using the same test as for sex-specific differences, we tested whether the refuges had the same annual rates of survival and recovery.

Simultaneous banding at all refuges occurred in sufficient numbers in 1963-70, inclusive. We could not reject the hypothesis that the three refuges had different survival or recovery rates (χ^2_{72} = 85.5, $p > .15$) where two age classes (young and adult) were distinguished.

More extensive data were available from Horseshoe Lake and Union County for banding conducted 1963-77. No differences in survival and recovery rates were detected (χ^2_{60} = 66.7, $p > .3$).

PRE- VS. POST-SEASON BANDINGS

Limited pre-season banding took place during several years. Sufficient bandings for analysis were available only in 1964-70 during which 4500 normally handled geese of known age (762 recoveries) were banded, 65% of these from Crab Orchard NWR and 35% from Union County and Horseshoe Lake refuges. Due to the relatively small numbers available, data for sexes and refuges were pooled without considering possible differences.

Pre-season banding occurred on the refuges just prior to the Illinois hunting season. Newly banded geese were those that survived earlier hunting in Canada, Wisconsin and Michigan, and then were exposed to further hunting during the Illinois quota-zone season. Thus first year recoveries were the result of exposure to only part of the fall hunting season. In addition first year recoveries included three age classes--juvenile, yearlings and adult. In contrast, recovery of post-season geese included only yearling and adults.

Since there was one year of age dependence in the post-season data we expected at least two years of age dependence in pre-season data to account for juveniles, yearlings and adults. A test of the need for such a model (H_2 vs. H_3) has confirmed this reasoning (Table 7). However, estimates for three age classes were not possible since yearling geese were not distinguished from adults at banding (Brownie et al. 1978: 116). Estimates of survival and recovery rates were made using model H_2 (Table 8). Under this model estimates were made for the part year recovery rates of juveniles (f') and first year adults (f'''), the annual recovery rate of adults (f) and the annual survival of juveniles (S') and adults (S).

TABLE 7. Hypothesis tests concerning properties of Survival and Recovery Rates from Pre-season Bandings.

Test	Null Hypothesis	χ^2	df	Signif.
Fit of H_{02}	Constant S, Year varying f	149.6	91	< .001
Fit of H_1	Year Varying S and f	104.9	65	< .001
Fit of H_2	Year Varying S and f, 1 yr. age dependent f	74.2	59	.090
Fit of H_3	Year Varying and 2 yr. + age dependent S&f	49.2	52	.550
H_1 vs. H_2	f age dependent 1 yr. only	30.7	6	< .001
H_2 vs. H_3	S&f age dependent 1 yr. only	24.2	7	< .001

Table 8. Survival and Recovery rate estimates From Pre-Season, 1962-1970.

Year Beginning late October	Juvenile Recovery		1st Yr. Adult Recovery		1st Yr. Recovery	2nd Yr. + Adult Recovery		Juvenile Survival		Adult Survival	
	Rate	SE	Rate	SE	Rate: Juv/Adult	Rate	SE	Rate	SE	Rate	SE
1964	.066	.017	.029	.013	2.3			.370	.106	.548	.148
1965	.014	.014	.038	.015	0.4	.068	.026	.684	.239	1.115	.220
1966	.075	.012	.023	.005	3.2	.035	.011	.653	.102	.684	.090
1967	.054	.010	.003	.002	18.0	.039	.007	.904	.184	.933	.182
1968	.037	.018	-	-	-	.023	.005	1.098	.283	.845	.185
1969	.074	.021	.013	.006	2.4	.031	.006	1.212	.382	1.149	.314
1970	.091	.018	.034	.012	2.7	.025	.007				
Average	.059	.006	.023	.004	2.6	.037	.005	.820	.097	.879	.054

The model did fit the data but not particularly well (P = .09). As a practical consequence, the survival of yearling and adults are combined into adult survival (S).

The average annual recovery rate for adult geese was .037 (Table 8). Part year recovery rates for juveniles and yearlings averaged .059 and .023 respectively. Survival of juveniles and adults was .820 and .879 respectively. All estimates have large sampling variances.

The pre-season bandings provide the only information on juvenile recovery rates available in the Illinois banding data. The average vulnerability of juveniles to adults is .059/.023 = 2.6 in the first year recovery rates. Since juvenile vulnerability may decline as the season progresses (Vaught and Kirsh 1966), this estimate may be conservative. From post-season bandings, the average recovery rate of yearlings to adults was .033/.027 = 1.2 for the same years. Thus, the relative vulnerability of the juvenile-yearling-adult age classes was 2.6 - 1.2 - 1.0, on the average. Inspection of individual years suggests considerable annual variation.

The MVP consists of early and late migrating segments of Canada geese. The early segment, about one-third of the population, gradually builds by mid-November. The late-migrating segment arrives 2-4 weeks later from a migrational stop at Horicon Refuge. Kennedy and Arthur (1974) calculated from harvest and population estimates that the early segment was harvested at a higher rate than the late segment. Banding data provide an independent way to address the same issue. The pre-season bandings are a sample from the early migrating segment and the post-season bandings probably contain both the early and late migrants.

Comparison of adult rates of annual recovery and survival were made from the pre- and post-season data (.037) than in post-season data (.026) for the same years ($Z = 2.04$, $p < .05$). This appears to support the results of Kennedy and Arthur (1974) that harvest of early migrants was larger during this period. No difference in average annual survival of adults in the pre-season (.879) and post-season (.859) was detected ($Z = 1.2$, $p > .20$).

If pre-season adults were indeed harvested at a higher rate, their vulnerability over post-season geese should be evident in certain recovery locations or during certain times in the hunting season. From Kennedy and Arthur (1974) we would predict a high rate of harvest for early season geese in southern Illinois up until the arrival of late geese from the Horicon migration. To examine this, we selected indirect recoveries of pre- and post-season geese for the years 1964-71. In these years, the Illinois quota zone season opened in mid-November, and most of the Horicon migration usually took place after December one.

During this period .335 and .255 of recovered pre- and post-season geese, respectively, were reported from Illinois. However, there was no tendency for pre-season geese to predominate the Illinois harvest prior to the Horicon migration ($\chi^2_4 = 3.5$, $p > .45$) (Table 9). We could find no recovery locations or periods within the fall hunting season where a differential harvest between pre- and post-season adults was evident.

Table 9. Temporal distribution of Indirect recoveries of Pre- and Post-Season geese in Illinois during 1964-71.

Date of Recovery	Pre-Season		Post-Season	
	Number	Proportion of total	Number	Proportion of total
October 16-31[1]	7	.07	63	.07
November 1-15	5	.05	93	.10
November 16-30	23	.23	201	.21
December 1-15	34	.34	384	.36
After December 15	31	.31	249	.26
TOTALS	100	1.00	990	1.00

[1] Most of harvest in east central Illinois, in later periods most of harvest in Illinois quota zone.

EFFECT OF RECRUITMENT AND HARVEST ON SURVIVAL AND RECOVERY RATES

In a previous section, we gave evidence that survival rates vary from year to year. It is important to know what factors contribute to the annual differences in survival, particularly in adults since they contain the breeding segment of the population.

The average vulnerability of juveniles in the fall harvest is much higher than adults. From our results, it is conservatively estimated as 2.6: 1. We believe that juveniles are a buffer to the harvest of adults, but the effectiveness of the buffer varies annually in response to harvest rate and recruitment level. For example, in years when reproduction is high, there is a high percentage of juveniles in the fall flight. If the harvest is low in that year, we would expect a high percentage of abundant, more vulnerable juveniles in the harvest. On the other hand, when reproduction is poor and the harvest is high, there are fewer juveniles in the fall flight so a greater percentage of the adult population should be harvested.

Assuming that the harvest of geese is an additive contribution to mortality at existing harvest levels, we would predict survival of adults to be high in years of high recruitment and low harvest, and low in years of low reproduction and high harvest. Such differences would explain, in part the observed variability in survival rates. The same pattern might also be expected for young, i.e. geese shot as yearlings, although it would be more difficult to detect. Since young are more vulnerable than adults (1.2 - 1 from post-season data recovery rates) expected differences would be smaller. Also estimates for young are

subject to much more sampling variation and small differences may not be detected.

An index to annual harvest rate was constructed from the post-season MVP size (Mid-winter aerial inventory) and the estimated animal harvest (Mail Questionnaire Survey). Harvest Index was computed as:

$$\text{Harvest Index} = \frac{\text{Illinois + Wisconsin Harvest}}{(\text{Winter Population size}) + (\text{Illinois + Wisconsin Harvest})}$$

Only harvest estimates from Illinois and Wisconsin were used since these states account for more than two-thirds of the annual harvest and figures from other states included geese with other population affiliations. Recovery rates calculated from band recoveries are also an index to harvest. However, we cannot use these to evaluate the impact of harvest on survival rates. Recovery and survival rates from the banding data have a high sampling correlation (-.2 to -.6) in the same direction we would predict if harvest were influencing survival rate. Harvest Index and annual recovery rates for 1962-74, are poorly correlated in both young ($r = -.07$, $p > .80$) and adults ($r = .26$, $p < .40$). While this might suggest that Harvest Index is a poor index to harvest rate, the poor correlation between these indicies does not necessarily indicate that. First, recovery rates during this period vary over only a small range (.020 - .037 for adults, .012 - .042 for young). And second, Harvest Index is a measure of overall population harvest while recovery rates are indicative of particular age classes only.

As an index to annual recruitment, we used the post-season age ratio in the Union County Bandings. The age ratios were based on large

numbers of geese banded in walk-in traps. More accurate indicies might be available from sources earlier in the fall, before age ratios are appreciable affected by the harvest. Age ratios from the parts collection were small and showed inconsistant variation in the relevant states. Post-season age ratios reveal the desired trends but the magnitude of differences observed between good and poor reproduction years are probably reduced.

From these data, we determined the years of high and low recruitment for 1962-74 (Table 10). The mean Recruitment Index for these years was .597. Years above this value were classified as high recruitment years. For the same period, years of high and low harvest were similarly classified using Harvest Index. Thus four classes were determined. Favorable conditions of low harvest and high reproduction occurred in 1962, 1963, 1967, 1968, and 1971. Adverse conditions of high harvest and low reproduction occurred in 1966, 1970, 1972, and 1973. Intermediate conditions of high reproduction and high harvest occurred in 1964, 1965, and 1974.

Survival and recovery rates for post-season young and adults are summarized in Table 11 under the four conditions of harvest and recruitment. We tested 4 hypotheses for each parameter--Low vs. High harvest, Low vs. High recruitment, harvest X recruitment interaction, and the years of favorable vs. unfavorable conditions (Table 12). All tests were formulated using appropriate linear model techniques which give rise to a χ^2 test statistic (Grizzel et al. 1969). These tests are equivalent to the Z tests used previously but they are structured so that more type of questions can be asked. (To demonstrate the equivalence of the tests notice that $\chi^2_{(1)} = Z^2$. This will be more fully developed in the final report.)

Table 10. Harvest and Recruitment Indicies for MVP, 1962-74.

	Recruitment Index		Harvest Index			
Year	Banded in Union Co.	Prop. Juv.	Ill. + Wisc.[1] Harvest	Post-Season[2] Population	Index	Level Recruitment-Harvest[3]
1962	499	.61	30,500	159,000	.16	H-L
1963	984	.61	30,000	196,000	.14	H-L
1964	3581	.78	70,500	178,000	.28	H-H
1965	5214	.77	66,500	186,000	.26	H-H
1966	5760	.54	56,000	162,000	.26	L-H
1967	5346	.71	56,000	209,000	.21	H-L
1968	4466	.68	46,000	288,000	.14	H-L
1969	4781	.45	72,000	324,000	.18	L-L
1970	1753	.50	66,500	292,000	.25	L-H
1971	4007	.62	96,000	294,000	.19	H-L
1972	2133	.44	69,500	296,000	.25	L-H
1973	2378	.54	89,000	278,000	.29	L-H
1974	2745	.62	124,000	304,000	.27	H-H
mean		.60			.22	

[1] Mail-Questionnaire Survey

[2] Mid-winter Aerial Inventory

[3] H=High, L=Low

Table 11. Summary of Survival and recovery rates by harvest and recruitment status, 1962-74.

		Recruitment Level	
Harvest Level	Parameter	High	Low
High	$\bar{S}$	.812	.770
	$\bar{S}'$	.827	.745
	$\bar{f}$	.030	.027
	$\bar{f}'$	.032	.037
Low	$\bar{S}$	.937	.806
	$\bar{S}'$	.749	.841
	$\bar{f}$	.027	.026
	$\bar{f}'$	.028	.036

Table 12. Test results of hypotheses regarding differential survival and recovery rates between levels of annual harvest and recruitment.[1]

EFFECT	Adult Survival $\chi^2_{(1)}$	Adult Survival Signif.	Adult Recovery $\chi^2_{(1)}$	Adult Recovery Signif.	Young Survival $\chi^2_{(1)}$	Young Survival Signif.	Young Recovery $\chi^2_{(1)}$	Young Recovery Signif.
Harvest	2.60	.11	2.30	.16	0.03	> .90	1.12	.28
Recruitment	3.68	.08	2.30	.16	0.09	> .90	0.40	.49
Interaction	1.05	.35	0.57	.44	2.81	.10	7.58	.005
Favorable vs. unfavorable survial conditions[2]	8.72	.004	0	1.00	0	1.00	0.11	.7

[1] All significance levels assume a 2-sided test.

[2] Years of high reproduction and low harvest versus years of low reproduction and high harvest.

Adult survival was .916 in low harvest years and .786 in high harvest years. In years of high and low recruitment, adult survival was .887 and .779, respectively. Tests for these differences, while not completely persuasive, suggest that each factor may influence adult survival rates (Table 12). Adult survival in favorable years of low harvest and high recruitment was .937, and in unfavorable years of high harvest and low recruitment adult survival was .770. This difference ($p < .004$) suggest that both factors simultaneously influence adult survival rate.

While we might expect adult-recovery rates to exhibit a pattern complementary to that for survival, no differential recovery rates were detected between levels of harvest and recovery (Table 12). As previously indicated, adult recovery estimates varied little during these years.

Neither survival nor recovery rates of young geese showed marginal differences due to either recruitment or harvest. However, an effect due to the interaction of harvest and recruitment was indicated in recovery rates, and somewhat less so, in survival rates (Table 12). We know of no biological reasons why this might occur.

SUMMARY

1. Estimates of annual survival and recovery rates were made from 12,000 recoveries of 92,000 geese banded in southern Illinois from 1941-77.

2. No differences in survival or recovery rates were detected between males and females. Also, no differences were detected between geese banded at Horseshoe Lake, Union County, and Crab Orchard refuges. These data were pooled for analysis.

3. Recovery rates for young and adults averaged .034 and .031 during 1941-47, .055 and .053 during 1951-59, and .033 and .028 during 1960-77. Average recovery rates were detectably different between young and adults only in the later period.

4. Survival rates for young and adults averaged .796 and .747 during 1941-47, .598 and .798 during 1951-59, and .771 and .812 during 1960-77. Differences between young and adults were detected in the later two periods.

5. Statewide hunting regulations were used in the 1950's to control harvests while quota zone regulation continued after 1960. Both survival and recovery rates were more variable in the 1950's. There was no difference in average adult survival between these periods, however, juvenile survival was significantly lower in the earlier period.

6. Recovery rates generally declined from 1951-77. Much of the decline is probably due to lower reporting rates. If the decline is consistant from year to year, survival rates are not appreciably affected.

7. Survival rates were shown to vary from year to year. Large annual differences existed in both young and adults. There was general agreement between the variability in survival rates and historical accounts of MVP harvest levels.

8. Part of the annual variation in adults might be due to a buffering effect from juveniles that is different in different years. Survival of adults was shown to vary with annual recruitment and harvest. Adult survival in years of high recruitment and low harvest (.937) was significantly higher than survival in years of low recruitment and high harvest (.770). No differences were found for survival of young or the recovery of either young or adults.

9. Estimates were also made from 780 recoveries of 4500 geese banded in the pre-hunting season period during 1964-70. Due to small numbers banded and recovered, large sampling variances and covariances were associated with these estimates.

10. Average survival from pre-season bandings were .820 for young and .879 for adults. These estimates are probably somewhat biased because a proper model could not be fit.

11. While survival estimates from pre-season bandings are higher, they are not significantly greater than survival rates from the post-season period for either age class.

12. Pre-season adults had a significantly higher recovery rate (.037) than their post-season counterparts (.028) during the same years. Part of this may be due to bias that would tend to inflate the pre-season estimates. However, the difference supports data presented by Kennedy and Arthur (1979).

13. There was no way to account for higher adult recovery rates in pre-season geese. Both pre- and post-season geese were recovered in similar proportions in all harvest areas. They did not dominate the Illinois harvest prior to the Horicon migration as might be expected.

14. Recovery rates from pre- and post-season bandings indicate that the relative harvest rate for juveniles-yearlings-adults is 2.6 - 1.2 - 1.

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